Europa SDT Meeting #11

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SDT #11 Meeting Agenda

10:45	*Adjourn Europa Plume Forum*	
11:00	Update from NASA HQ (15 min)	C. Niebur
11:15	Project update (15 min)	T. Magner
11:30	Plume workshop recap discussion (30 min)	All
12:00	***Lunch (75 min)***	
	Lunch talk: "Detecting Europa's induction response from multiple flybys"	B. Bills
1:15	Trajectory evaluation summary (30 min)	S.Vance/K. Craft
1:45	Final consensus on Science and Recon Traceability Matrices (45 min)	D. Senske/L. Prockter
2:30	SDT comments on SRRD (30 min)	B. Paczkowski/K. Craft
3:00	SDT summary notes (bullet slides) for Niebur as output (15 min)	L. Prockter/D. Senske
3:15	Closing remarks (15 min)	C. Niebur/ L. Prockter
3:30	*Adjourn*	

Project Update

Thomas Magner

6/3/14

Major Accomplishments Past 12 Months

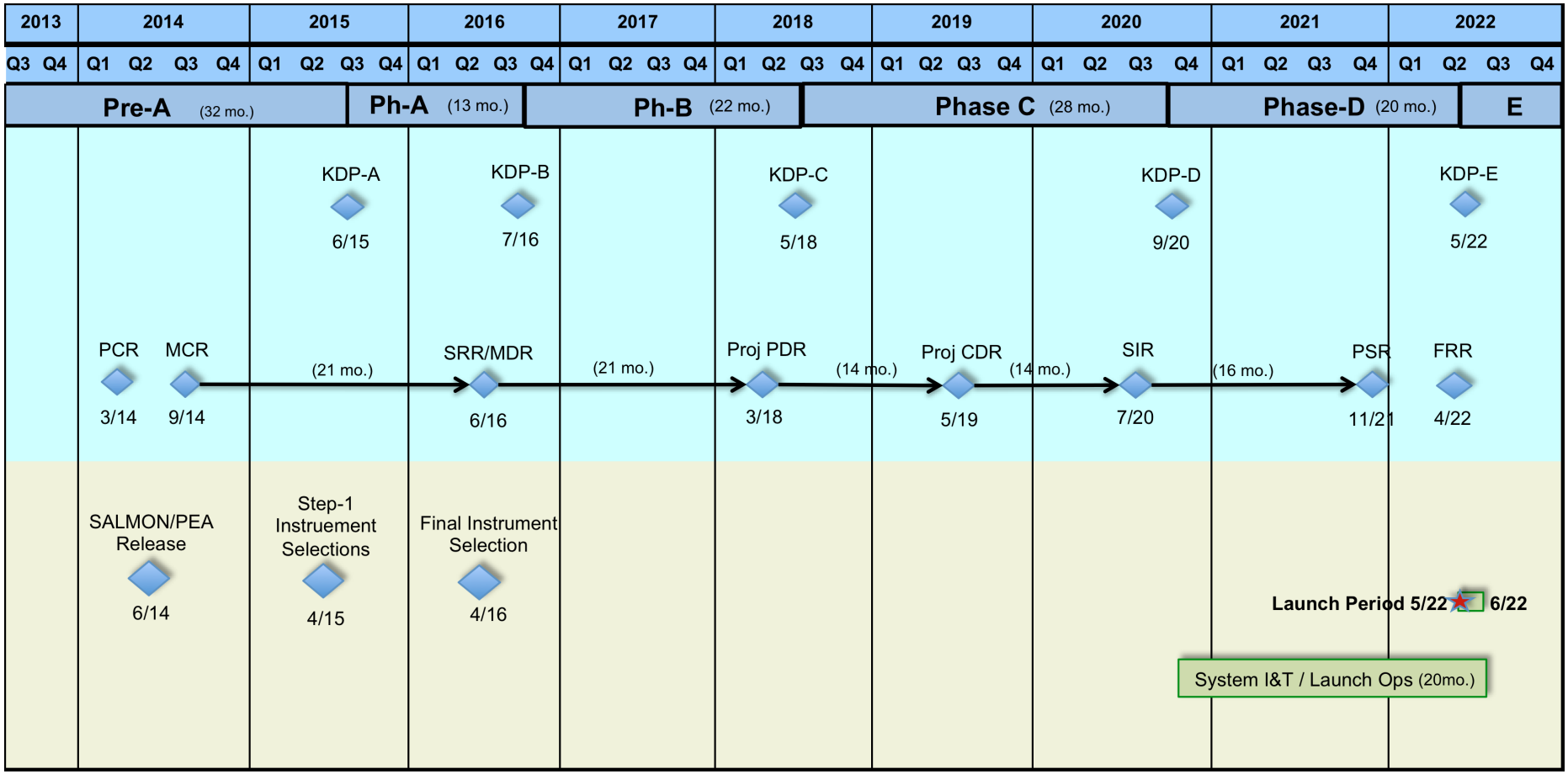
1. Reference tour, *"13-F7"*, established and certified by science team
   - Subsequent tour designs will use this as the basis
2. Successful solar array feasibility study
3. Updated S/C design to stacked tank configuration
4. Established agreement on roles and responsibilities between APL and JPL
5. Conducted two successful Project requirements reviews
6. Populated initial version of preferred parts List
   - Procured and tested for radiation and planetary protection processing a significant number of EEE parts & materials for engineering and payload
7. Conducted successful Preliminary Concept Review (PCR)
8. Continued significant science community engagement
9. Established integrated master schedule in support of the development of the baseline architectural design

Key Open Trades/Decisions

- Launch Year ➔
  - 2022 (Baseline) or 2024
- Launch Vehicle ➔
  - Space Launch System (SLS) or ATLAS-V 551
- Power Source ➔
  - Solar Arrays or MMRTGs

NOTE: MMRTGs not available to support 2022 launch per RPS Program

Top Level Project Milestones



Planned Major Accomplishments Next 12 Months

1. Complete Proposal Information Package in support of SALMON PEA release in June/July of 2014
2. Complete environmental tests for solar arrays to assess capability for mission baseline
3. Conduct solar baseline review (8/19/14 – 8/20/14)
4. Conduct Mission Concept Review (9/16/14 – 9/18/14)
5. Continue parts and materials test program
6. Begin repackaging of proto-type avionics hardware & software to establish Clipper system test-bed
7. Produce two copies of baseline radio
   - One unit to undergo radiation tests to Clipper requirements
   - Second to populate system test-bed
8. Continue lower level requirements generation in preparation for System Requirements Review (SRR) and Mission Definition Review (MDR)
9. Integrate cost baseline into Project master schedule and evaluate optimal subsystem start times to control funding profile

Plume Advisory Meeting: Summary of Key Findings

Plume Forum: Key Findings

A. Evidence for Europa eruptive plumes is intriguing but not definitive. Plumes have exciting science potential in exposing subsurface material but today remain unconfirmed moreover their source is unconstrained.

B. Plumes are currently unpredictable, if they exist, could have spatial and/or temporal variability that could plausibly be cyclical, episodic, or sporadic, on uncertain time scales and with uncertain location; this range of possibilities should be considered in developing potential observation strategies, using the payload ultimately selected by NASA.

C. Based on the available evidence, plume investigations should not drive Europa mission concepts, but should be compatible with the Decadal Survey-recommended mission objectives and investigations for Europa. [*Note: Revise this wording to begin with statement of Decadal Survey*.]

D. The Cassini experience at Enceladus shows the great scientific value of a broad and capable suite of instruments in addressing plume science.

E. The Europa Clipper tour design and operations concept should remain adaptable to possible future plume discoveries.

F. Further searches for, and research into, possible plumes will help to guide decisions on how to optimize investigations of plumes with Europa Clipper.

G. The plausible characteristics of Europa plumes should be analyzed and modeled for consideration of spacecraft low-altitude safety.

13F7-A21 Trajectory vs. Science and Recon Requirements

Wes Patterson, Steve Vance, Louise Prockter, Kate Craft, Andy McGovern, Scott Turner

Overview

- Task definition
- Flow of requirements to specific straw-man instruments
- Analysis results per instrument
  - Pointed
  - Non-pointed

Trajectory vs. Requirements Task

- Link each Science and Recon requirement to an instrument operation and determine at which fly-by the requirement is met
  - Enables determination of when (or if) the trajectory will satisfy each requirement
  - Calls attention to requirements that are not met until late in the mission (risk) → the "Tall Poles"
  - Allows realization of "missed fly-by" consequences and which fly-bys contribute significantly or least towards achieving the requirement
- This analysis performed with single iteration model runs and "by hand"
  - Trajectory analyses "tool" in development at APL

Flow of Requirements to Instrument

- Requirements in Science and Recon Matrices linked directly to an observation by a certain instrument
- Observations assessed by:
  - Cumulative value of observations

    Or
  - Percentages of coverage that meets requirement per fly-by
- Highlighting:
  - White = not collecting data
  - Blue = observations are occuring, but no requirement met yet
  - Yellow = floor requirement met
  - Green = baseline requirement met

Flyby #	Panels	
	Hi-res Mode	Lo-res Mode
	Required: 8 of 14 Desired: 11 of 14	
1	N/A	7
2	2	7
3	4	7
4	4	7
5	4	7
6	7	7
7	7	7
8	7	7
9	7	7
10	7	7
11	7	7
12	7	7
13	7	7
14	7	7
15	N/A	9
16	N/A	9
17	7	10
18	7	10
19	7	10
20	7	10
21	7	10
22	7	10
23	7	10
24	7	10
25	8	11
26	8	11
27	8	11
28	8	11
29	9	14
30	N/A	14
31	11	14
32	12	14
33	13	14
34	14	14

SWIRS

	Operation		Coverage						
			Areal		Distribution				
					Hi-res Mode			Panels	
		Hi-res Mode	Hi-res Mode	Lo-res Mode				Hi-res Mode	Lo-res Mode
Flyby #	Spacecraft velocity at closest approach* (< 6 km/s)	Spacecraft altitudes < 1000 km (*currently < 650 km*)	100 representative landforms (assuming every image includes a landform)	Global-scale coverage over the surface 70% Desired 50% Required	Observations on the leading hemisphere are required	Observations on the trailing hemisphere are required	Observations at high latitude are required	Required: 8 of 14 Desired: 11 of 14	
1	4.33	752.7	N/A	4.98%	N/A	N/A	N/A	N/A	7
2	4.36	250	5	7.82%	2	3	[illegible]	[illegible]	7
3	4.42	100	13	10.03%	4	4	[illegible]	[illegible]	7
4	4.43	100	21	12.24%	4	4	43.69%		7
5	4.44	50	31	14.72%	6	[illegible]	[illegible]		7
6	4.44	25	45	15.36%	8	6	49.93%		7
7	4.40	100	53	15.56%	4	4	[illegible]		7
8	4.43	100	61	16.28%	4	4	53.60%		7
9	4.47	25	75	17.17%	8	6	[illegible]		7
10	4.47	50	85	18.99%	6	4	57.01%		7
11	4.48	25	99	21.24%	8	6	[illegible]		7
12	4.46	50	109	22.01%	6	4	58.22%		7
13	4.46	25	123	22.28%	8	6	[illegible]		7
14	4.28	565.2	123	22.86%	0 (1)	0 (1)	59.87%		7
15	4.19	1872.2	N/A	26.46%	N/A	N/A	[illegible]		9
16	4.26	2710.3	N/A	27.89%	N/A	N/A	61.33%		9
17	4.48	50	133	29.94%	10	0	[illegible]		10
18	4.48	50	143	30.36%	2	8	[illegible]		10
19	4.49	81.2	151	31.49%	8	0	62.59%		10
20	4.51	50	161	31.49%	1	9	[illegible]		10
21	4.49	100	169	32.43%	7	1	63.25%		10
22	4.51	50	179	32.46%	1	9	[illegible]		10
23	4.54	50	189	33.63%	10	0	64.72%		10
24	4.53	100	197	34.05%	1	7	[illegible]		10
25	4.56	50	208	39.57%	5	6	65.35%		11
26	4.58	50	218	41.73%	5	5	[illegible]		11
27	4.58	50	228	42.65%	2	8	65.56%		11
28	4.61	25	228	43.69%	0	0 (14)	[illegible]		11
29	4.35	546.7	228	49.93%	0 (2)	0	66.28%		14
30	4.35	1009	N/A	53.60%	N/A	N/A	[illegible]		14
31	4.45	100	236	57.01%	4	2	66.74%		14
32	4.43	100	244	58.22%	4	4	[illegible]		14
33	4.43	50	255	59.87%	5	6	67.47%		14
34	4.43	50	266	61.33%	5	6	[illegible]		14
35	4.45	25	280	62.59%	7	7	67.99%		14
36	4.32	303.4	284	63.25%	0	4	[illegible]		14
37	4.37	50	295	64.72%	6	5	68.03%		14
38	4.28	25	310	65.35%	12	3	[illegible]		14
39	4.30	50	321	65.56%	2	9	68.15%		14
40	4.29	25	336	66.28%	12	3	[illegible]		14
41	4.29	50	347	66.74%	2	9	0	14	14
42	4.29	50	358	67.47%	9	2	6	14	14
43	4.26	25	373	67.99%	2	13	0	14	14
44	4.24	50	373	68.03%	0 (9)	0 (2)	0 (9°)	14	14
45	4.19	25	388	68.15%	4	11	0	14	14

Tall Pole

Trajectory Analysis
Short-Wave Infrared Spectrometer (SWIRS)

Driving requirement(s):

- The ≥ 70% surface coverage requirement of the science traceability matrix for SWIRS data with resolution ≤ 10 km/pixel (*C.3a*) is not fully achieved with this trajectory – i.e., a surface coverage of 68% is reached by the 45th flyby, provided all flybys are successful.

Critical flyby(s):

- The 1st, 25th, and 29th flybys each contribute ≥ 5% surface coverage toward achieving the 70% coverage requirement of measurement *C3.a*.

Trajectory Analysis
Ice-Penetrating Radar (IPR)

Driving requirement(s):

- Achieving the coverage distribution requirement of the science traceability matrix (*IO.1a, IO.3a, IO.4a, IO.6a*) is the tallest pole for the IPR – i.e., intersecting groundtracks in 11 of 14 panels.
  - E.g., the requirement for intersecting groundtracks in each sub-Jovian panel is not met until flyby 43 for shallow mode operation, provided all previous flybys of the sub-Jovian hemisphere are successful.

Critical flyby(s):

- The 40th flyby in the 13F7-A21 trajectory satisfies coverage distribution requirements of the IPR shallow mode for 3 sub-Jovian panels.

Trajectory Analysis
Topo Imager (TI)

Driving requirement(s):

- Achieving the ≥ 70% surface coverage requirement of the science traceability matrix for TI data with resolutions ≤ 1 km/pixel (*G.2a*) is the tallest pole for the TI – i.e., the requirement is not met until flyby 38, provided all previous flybys are successful.
- The ≤ 5 m/pixel Baseline resolution Recon requirement *SV.2b* is not achieved for this trajectory – i.e., the highest resolution achieved by the TI for this trajectory is 6.25 m/pixel.

Critical flyby(s):

- The 1st, 3rd, 6th, and 33rd flybys each contribute ≥ 4% surface coverage toward achieving the 70% coverage requirement of measurement *G2.a*.

Trajectory Analysis
Reconnaissance Camera (RC)

Driving requirement(s):

- Achieving the stereo requirements of the reconnaissance traceability matrix (*SC.2a*) is the tallest pole for the RC
- The 5 x 10 km areal coverage requirement of the reconnaissance traceability matrix for RC data (*SC.1A, SC.2b, SC.3b, SC.4b, and SV.2a*) is not achieved for this trajectory – i.e., the maximum cross-track width achieved is 4.6 km.

Critical flyby(s):

- There are no identifiable critical flybys for this trajectory.

Trajectory Analysis
Thermal Imager (TherI)

Driving requirement(s):

- Achieving the surface coverage at two different times of day requirement of the reconnaissance traceability matrix (*SC.4a*) is the tallest pole for the TherI – i.e., only 8% coverage of the surface is achieved by the 45th flyby.

Critical flyby(s):

- There are no identifiable critical flybys for this trajectory.

Trajectory Analysis
Radio Science (RS)

Driving requirement(s):

- Recovering the k_2 amplitude at Europa's orbital frequency to 0.05 absolute accuracy (IO.5a) is the tallest pole for the RS – i.e., the requirement is not met until flyby 45, provided all previous flybys are successful.

Critical flyby(s):

- The 16^{th} – 23^{rd} flybys increase the k_2 amplitude accuracy by 0.06.

Trajectory Analysis

Magnetometer (MAG), Langmuir Probe (LP), Neutral Mass Spectrometer (NMS)

Driving requirement(s):

- none

Critical flyby(s):

- none

Clipper Reconnaissance: Imaging for Block Abundance

Dave Senske

Block Abundance Issue

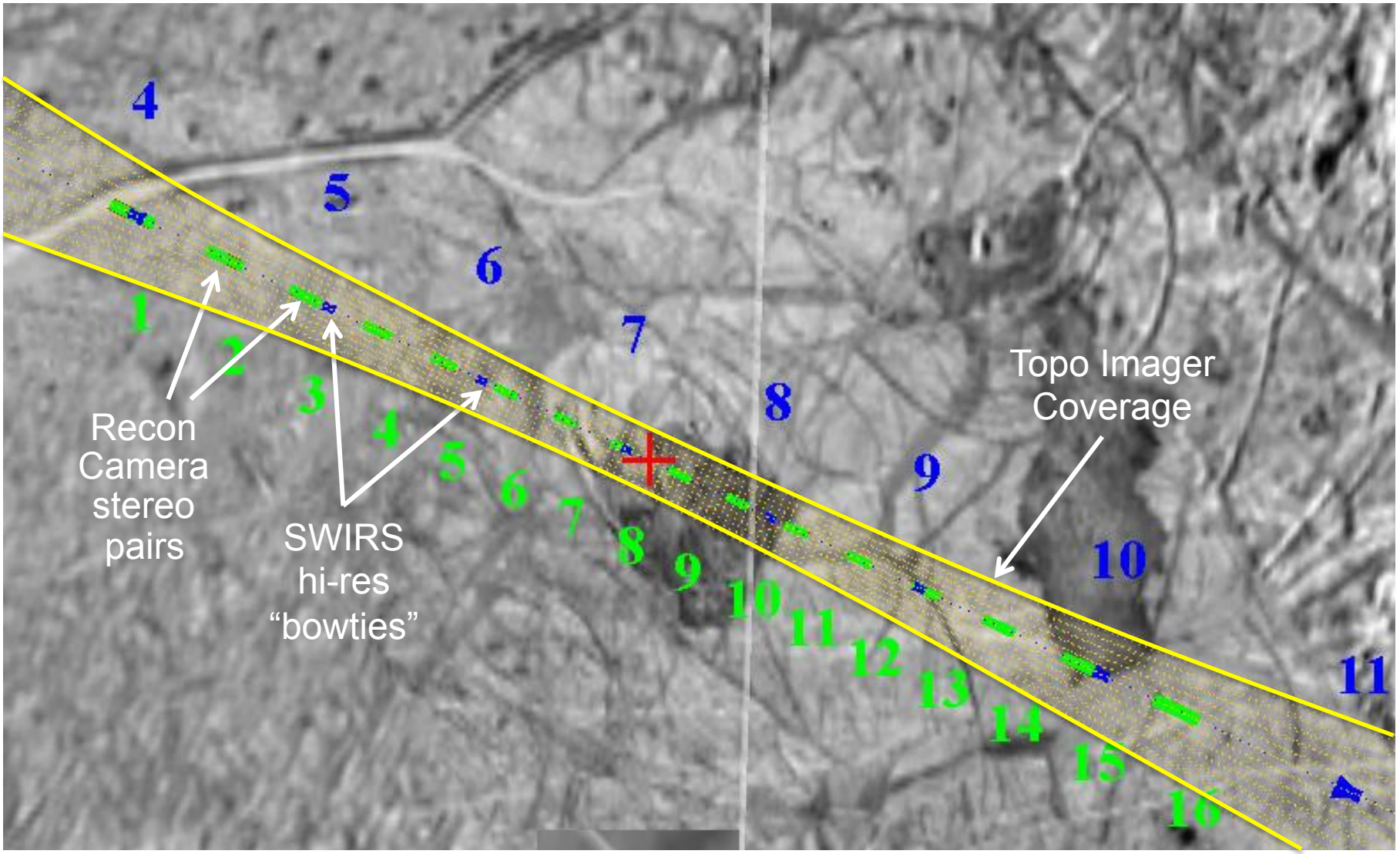
- Relevant Investigation:
  - "Determine the distribution of blocks and other roughness elements within a potential landing site at scales that represent a hazard to landing."
- At the 19 May 2014 SDT telecon, it was noted by Mike and Jeff that for assessing block abundance:
  - Images with high incidence angles (45° to 70°) may be required, to identify blocks by shadow measurements
  - Stereo identification is impractical to identify 1 meter blocks with 0.5 m/pixel imaging
  - Images with better than 30 cm resolution are needed to produce a 1 m resolution DEM [but is a 1 m DEM required?]
- Limiting Recon Camera observations to high incidence angle would:
  - Greatly limit the number and variety of features that can be imaged. (There are ~85 opportunities to acquire Recon images at incidence angles between 45° to 70° incidence.)
  - Negatively impact the SWIRS data, as the conflicting lighting requirements between SWIRS and Recon would mean that simultaneous observations would be suboptimal

Suggested Solution

- Current Recon TM Measurement Wording:
  - Measure the occurrence and lengths of shadows cast by blocks protruding 1 m or more above the surface, and the abundance and nature of surface roughness elements at scales of greater than 1 m, through monochromatic imaging at a spatial resolution on the surface of better than or equal to 0.5 m/pixel.
- Suggested Recon TM Measurement Wording:
  - Measure the occurrence **of blocks protruding 1 m and more above the surface, and the abundance and nature of surface roughness elements at scales equal to or greater than 1 m**.
- Such would leave it to proposers to determine and demonstrate the best way to address the block abundance investigation

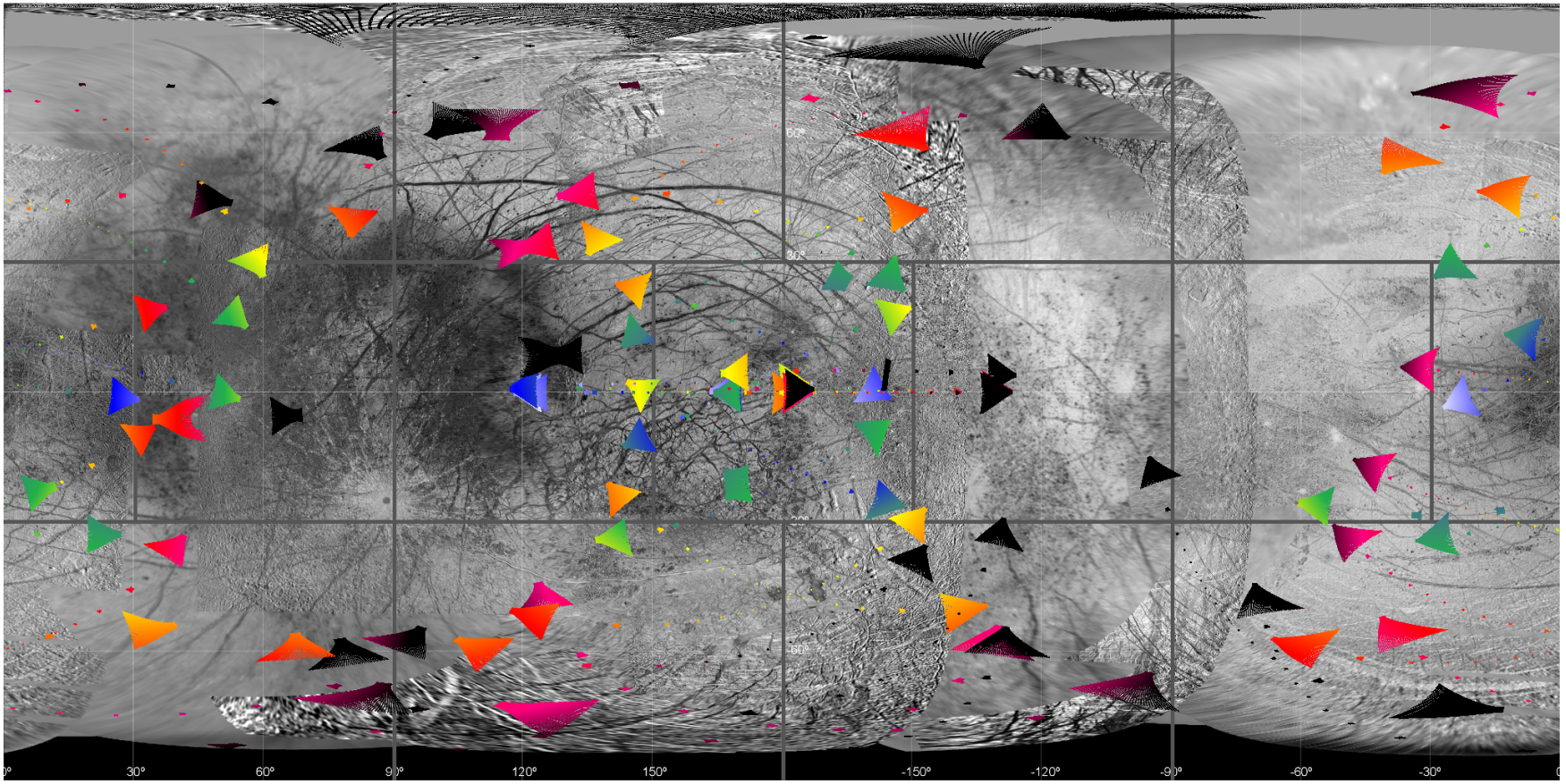
High-Resolution Reconnaissance

Topo Imager, Recon Camera, SWIRS (E6 Flyby): Incidence angle of 45 degrees

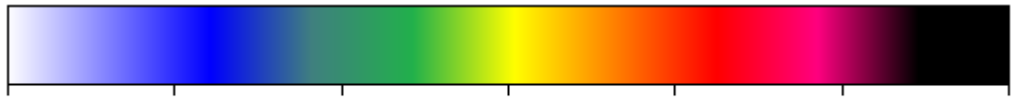


SWIRS High-Resolution Potential

Better than 300 m resolution, All Flybys



Lower incidence angles are layered on top



Lower incidence angles (cooler colors) are best for SWIRS

Pre-Decisional — For Planning and Discussion Purposes Only

Magnetic Field Measurements

Dave Senske

Proposal: Should magnetic measurements be added to a broader set of investigations?

- "Shallow water characterization"—IO.1 Characterize the distribution of any shallow subsurface water and the structure of the icy shell. - No
- "Search for Ice-ocean interface"—IO.3 Search for an ice-ocean interface. Add IO.3d – include current mag measurement
- "Ocean composition" - No

Proposed revision to LP measurement (1)

- Bagenal & Kurth proposed simplification of removing Measurement IO.2c and reducing Measurement IO.2b to:

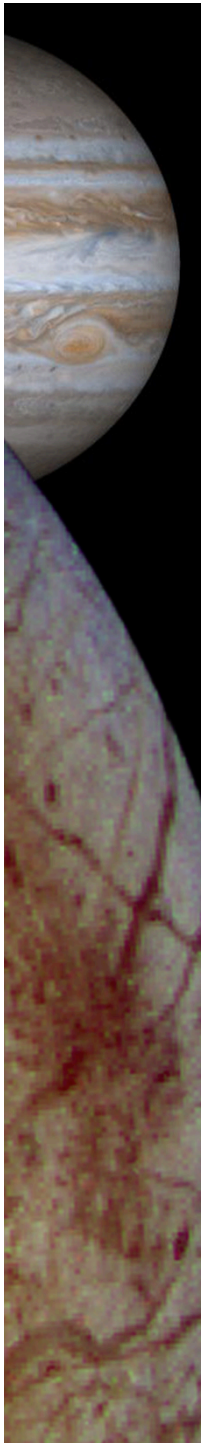
Characterize the local plasma environment to constrain (in conjunction with modeling) the contribution from currents not related to the surface and ocean.

Proposed revision to LP measurement (2)

- SDT discussion focused on reducing the specificity of Measurement IO.2b and leaving the details of the method to a future proposer.
- As the other measurements in the STM provide greater specificity, consensus of the SDT was to keep the original wording and retain Measurement IO.2c to keep consistency across the STM

Science and Reconnaissance Requirements Document

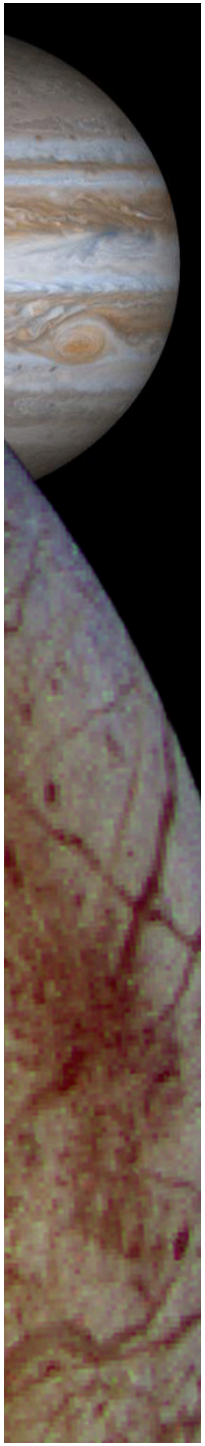
B. Paczkowski and K. Craft



Science and Recon Requirements Document

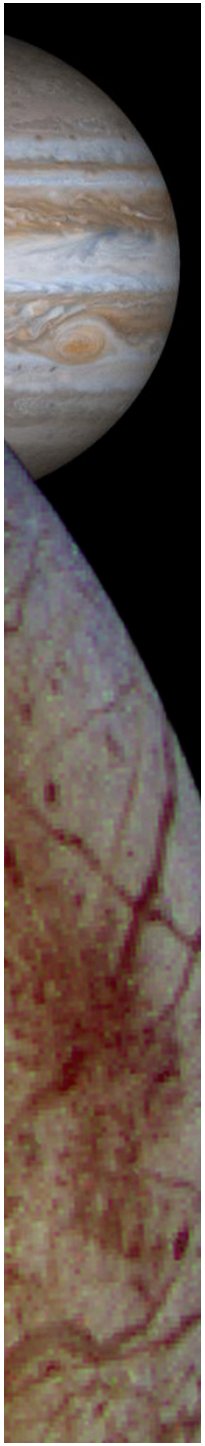
- Overview
  - Key gate product needed for the Mission Concept Review (9/2014)
  - Requirements will be used to guide the Flight System, Payload System, and Mission System (including Navigation) during concept development and initial design work
  - Detailed Project Level 3 & 4 requirements will be derived from these science and reconnaissance requirements
  - Requirements were developed using notional payload
  - Final requirements will be negotiated with the full Europa Clipper science team, comprised of the selected instrument teams

- The key source of the requirements are the Science and Reconnaissance Traceability Matrices
  - Science Traceability Matrix version 2.2 (5/28/14)
  - Recon Traceability Matrix version 5.1e (5/29/14)



Science and Recon Requirements Document

- General Document Philosophy
  - Maintain separation of science and reconnaissance requirements
  - Strive to write requirements agnostic to instrument selection
  - One measureable quantity per requirement
  - Use only STM or RTM baseline numbers in the requirements
  - Include science data quantity and quality requirements
  - Higher investigation-level requirements included for context



Requirements Document Structure

Program Level Requirements Documents

- Program Level Requirements and Constraints

Project Level 1 Requirements Documents

- L1 Mission Objectives and Constraints

Project Level 2 Requirements Documents

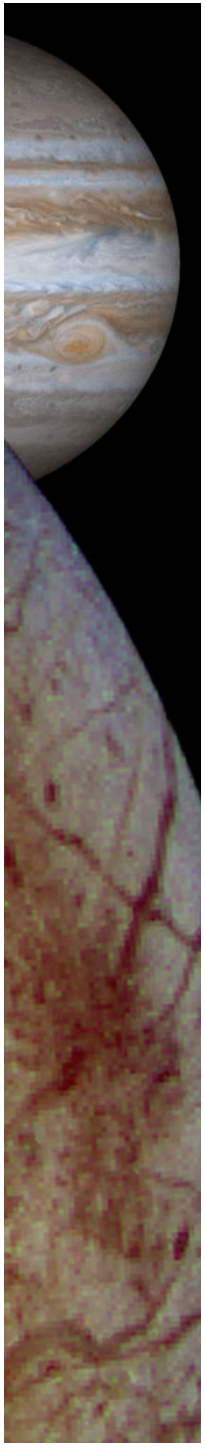
- Science and Reconnaissance Requirements Document
- Project Requirements Document
- Environmental Requirements Document
- Safety and Mission Assurance Requirements Document

Project Level 3 Requirements Documents

- Ground System Requirements Document
- Payload System Requirements Document
- Spacecraft System Requirements Document

Project Level 4 Requirements Documents

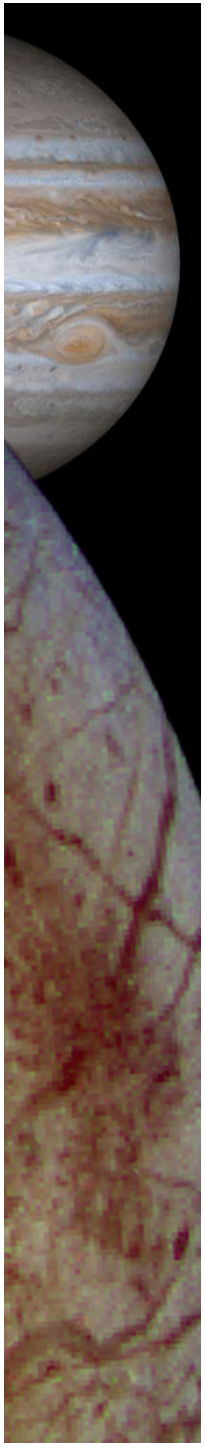
- Mission Operations System Requirements Document
- Instrument Requirements Document
- Spacecraft Subsystem Requirements Document



Science & Recon Requirements Metrics

Science Requirements Breakdown	Total
Ice Shell & Ocean Objective	
Investigation-Level Requirements	6
Measurement-Level Requirements	99
Composition Objective	
Investigation-Level Requirements	3
Measurement-Level Requirements	51
Geology Objective	
Investigation-Level Requirements	2
Measurement-Level Requirements	32
Total	**193**

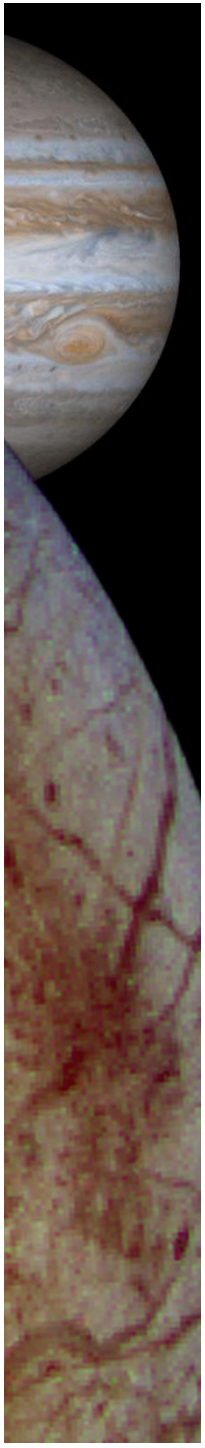
Recon Requirements Breakdown	Total
Landing Site Surface Properties Objective	
Investigation-Level Requirements	4
Measurement-Level Requirements	42
Landing Site Scientific Value Objective	
Investigation-Level Requirements	4
Measurement-Level Requirements	39
Total	**89**



Science Requirement Mapping

Investigation		Measurement		Mission constraints/requirements
IO.1	Characterize the distribution of any shallow subsurface water and the structure of the icy shell.	IO.1a	Identify and regionally characterize subsurface thermal or compositional horizons and structures related to the current or recent presence of water or brine. Obtain pairs of intersecting profiles of structures and subsurface dielectric horizons extending from 100 meters (desired) to 3 km (required) depth at 10-meter vertical resolution	(1) Acquire profiles through globally distributed regions: 6 equatorial panels (±30 deg Lat) and 4 panels at each pole (±60 deg in Lat) - total of 14 panels; (2) Require low-altitude flyby along a groundtrack achieving 800 km segments within each panel at altitude < 400 km at < 6 km/s. Two 800 km groundtrack segments in each sub-jovian panel and at least three 800 km groundtracks in each anti-jovian panel. Each groundtrack shall also intersect another groundtrack (intersection may be outside the panel of interest); a single radar pass of sufficient length and geometry may satisfy groundtrack and intersection requirements in adjacent panels; Floor: (1) & (2) satisfied in any 8 of the 14 panels including both anti- and sub-jovian equatorial panels;

	ID			Title	Requirement Text	Description / Clarification	Floor Requirement
Ice Shell & Ocean	SR.1			Shallow water characterization	The science observations shall characterize the distribution of any shallow subsurface water and the structure of the icy shell.	IO.1 Investigation	
		SR.1.1		Thermal & Compositional horizons	The shallow sounding profiles shall identify and regionally characterize subsurface thermal or compositional horizons and structures related to the current or recent presence of water or brine.	IO.1a in the science trace matrix.	th an
			SR.1.1.1	Intersecting Sounding Profiles	The shallow sounding profile data set shall be obtained in intersecting pairs.	IO.1a in the science trace matrix.	
			SR.1.1.2	Depth of Sounding profiles	The shallow sounding profiles shall penetrate the surface extending from 100 meters to 3 km depth.	IO.1a in the science trace matrix. There is no expectation of imaging shallower than (100m) due to surface interference. The depth requirement can be achieved with the assumption of a dialectric property and impurity concentration of Europa's ice sheet consistent with a two-way attenuation of TBS.	3 km
			SR.1.1.3	Resolution of sounding profiles	The shallow sounding profiles shall have a vertical resolution better than or equal to 10 meters.	IO.1a in the science trace matrix.	
			SR.1.1.4	Distribution and coverage of sounding profiles	The shallow sounding profiles shall have globally distributed regional coverage in at least any 11 of 14 panels.	IO.1a in the science trace matrix. For the purpose of the investigations, Europa's surface was divided into 14 panels, with 6 low latitude panels (±30 deg Lat) and 4 panels surrounding the poles (±60 deg in Lat), making a total of 14 panels.	8 of the 14 panels
			SR.1.1.5	Number of groundtrack segments	The shallow sounding profiles shall be obtained with a minimum of two 800 km long sounding profile groundtrack segments within each Sub-Jovian panel and a minimum of three 800 km long sounding profile groundtrack segments within each Anti-Jovian panel.	IO.1a in the science trace matrix. A groundtrack is the projection of the spacecraft (S/C) trajectory onto the surface of Europa. A groundtrack segment is a portion of a groundtrack.	
			SR.1.1.6	Number of intersections per panel	The distribution of the shallow sounding profiles shall result in at least one groundtrack intersection within each panel.	IO.1a in the science trace matrix.	
			SR.1.1.7	Sounding profile acquisition altitude	Each 800 km groundtrack segment shall be acquired when the spacecraft range to the surface of Europa is <400 km.	IO.1a in the science trace matrix.	



Selected Ice Shell and Ocean Requirements

SR.1.1 Thermal and Compositional Horizons

The science observation data set shall identify and regionally characterize subsurface thermal or compositional horizons and structures related to the current or recent presence of water or brine.

SR.1.1.1 Intersecting Sounding Profiles

The shallow sounding profile data set shall be obtained in intersecting pairs.

SR.1.1.2 Depth of Sounding Profiles

The shallow sounding profiles shall penetrate the surface extending from 100 meters to 3 km depth.

SR.1.1.3 Resolution of Sounding Profiles

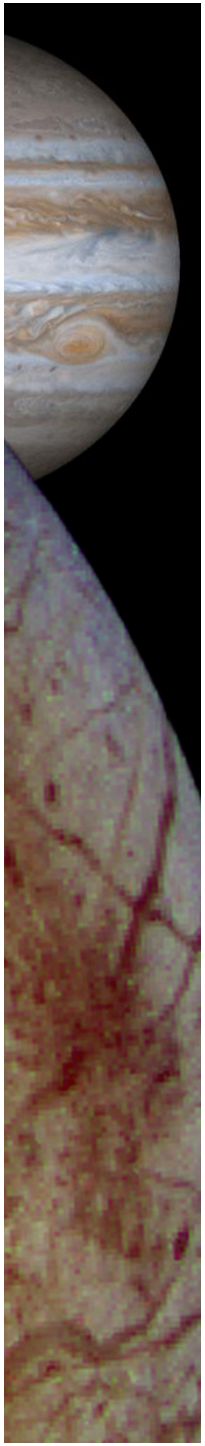
The shallow sounding profiles shall have a vertical resolution better than or equal to 10 meters.

SR.1.1.4 Distribution and Coverage of Sounding Profiles

The shallow sounding profiles shall have globally-distributed regional coverage of at least any 11 of 14 panels.

SR.1.1.5 Number of Groundtrack Segments

The shallow sounding profiles shall be obtained with a minimum of two 800 km long sounding profile groundtrack segments within each Sub-Jovian panel and a minimum of three 800 km long sounding profile groundtrack segments within each Anti-Jovian panel.



Selected Composition Requirements

SR.9.1 Surface Composition Measurement Type

The surface composition data set shall consist of spectral reflectance data in the wavelength range from 850 nm to 5000 nm.

SR.9.1.1 Surface Composition Data Set Distribution

The surface composition data set shall target at least 100 representative landforms at global-scales that are globally-distributed in at least any 11 of 14 panels with coverage in both the leading and trailing hemispheres of Europa.

SR.9.1.2 Spectral Resolution below 2500 nm

The infrared reflectance spectra shall have a spectral resolution better than or equal to 10 nm below 2500 nm.

SR.9.1.3 Spectral Resolution above 2500 nm

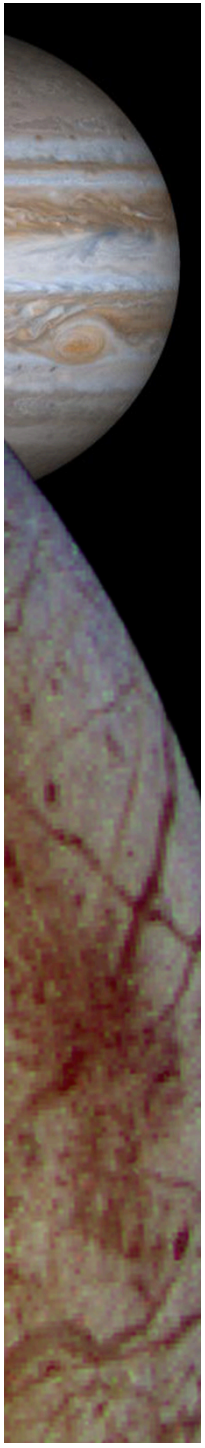
The infrared reflectance spectra shall have a spectral resolution better than or equal to 20 nm from 2500 nm to 5000 nm.

SR.9.1.4 Local Spatial Resolution

The surface composition data set shall have a local-scale spatial resolution better than or equal to 300 meters/pixel.

SR.9.1.5 High Latitude Data Coverage

The surface composition data set shall include at least one observation at a high latitude of greater than 45°.



Selected Geology Requirements

SR.10.1 Geological Activity Characterization

The geological activity data set shall characterize selected targets and their topography at better than 100 m horizontal scale.

SR.10.1.1 Surface Topography Vertical Resolution

The surface topography data set shall have a vertical resolution better than or equal to 10 m.

SR.10.1.2 Surface Topography Vertical Accuracy

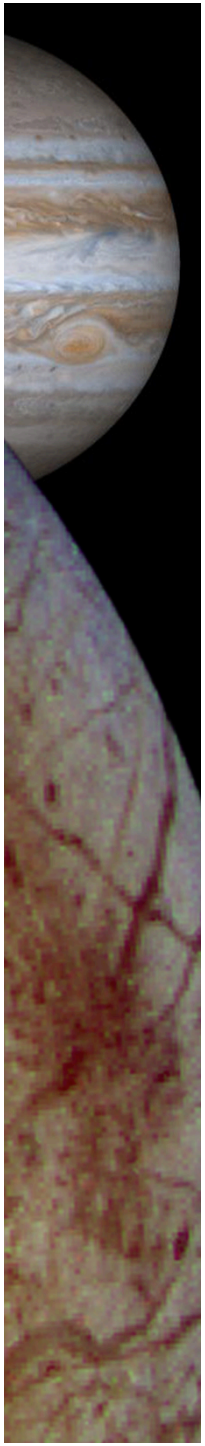
The surface topography data set shall have a vertical accuracy better than or equal to 10 m relative to TBS.

SR.10.1.3 Lighting for characterization of sites of recent geological activity

The geologic feature mapping data set shall be acquired when the solar incidence angles is in the range of 20 degrees to 80 degrees.

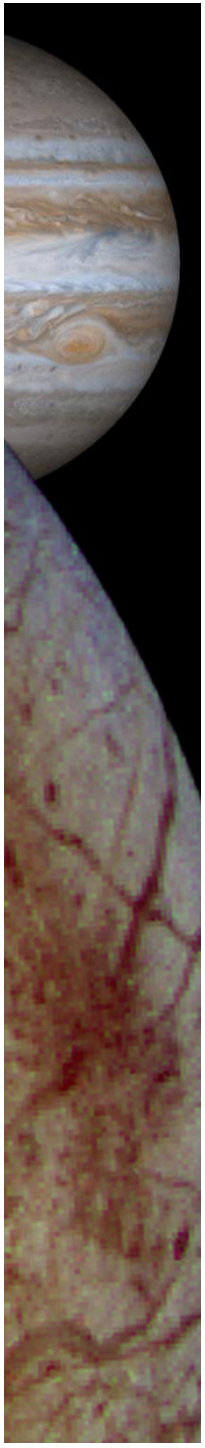
SR.10.1.4 Target selection for geological activity characterization

The geologic features targeted shall lie along the spacecraft groundtrack.



Science Requirements Open Issues

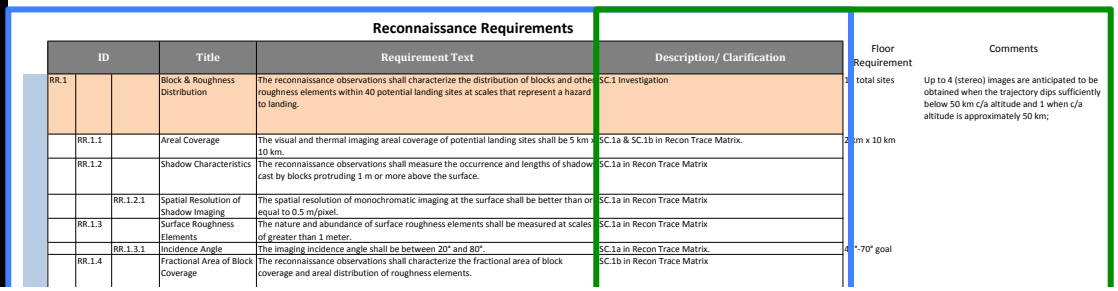
- Need SDT help to resolve TBSs contained in a few requirements
  - Altimetry measurement accuracy
  - Sounding profile depth assumption description
  - Sounding profile groundtrack and altimetry co-location accuracy
  - Relative surface topography vertical accuracy definition
  - Surface composition data set smear requirement
  - Minimum Sun-earth-probe (SEP) angle for gravitation tides measurement
- Strive to develop more specific science quality requirements



Reconnaissance Requirements

- Broken into two main topics (in same way as Recon Trace Matrix:
  - Surface Properties Characterization
  - Scientific Value of Landing Sites
- Requirements taken directly from trace matrix
- Challenges:
  - Making specific requirements with only a notional payload

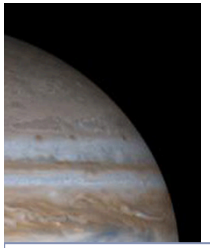
Landing Site Surface Properties



Reconnaissance Requirements

ID	Title	Requirement Text	Description/ Clarification	Floor Requirement	Comments
RR.1	Block & Roughness Distribution	The reconnaissance observations shall characterize the distribution of blocks and other roughness elements within 40 potential landing sites at scales that represent a hazard to landing.	SC.1 Investigation	15 total sites	Up to 4 (stereo) images are anticipated to be obtained when the trajectory dips sufficiently below 50 km c/a altitude and 1 when c/a altitude is approximately 50 km;
RR.1.1	Areal Coverage	The visual and thermal imaging areal coverage of potential landing sites shall be 5 km x 10 km.	SC.1a & SC.1b in Recon Trace Matrix.	2 km x 10 km	
RR.1.2	Shadow Characteristics	The reconnaissance observations shall measure the occurrence and lengths of shadows cast by blocks protruding 1 m or more above the surface.	SC.1a in Recon Trace Matrix		
RR.1.2.1	Spatial Resolution of Shadow Imaging	The spatial resolution of monochromatic imaging at the surface shall be better than or equal to 0.5 m/pixel.	SC.1a in Recon Trace Matrix		
RR.1.3	Surface Roughness Elements	The nature and abundance of surface roughness elements shall be measured at scales of greater than 1 meter.	SC.1a in Recon Trace Matrix		
RR.1.3.1	Incidence Angle	The imaging incidence angle shall be between 20° and 80°.	SC.1a in Recon Trace Matrix.	45°-70° goal	
RR.1.4	Fractional Area of Block Coverage	The reconnaissance observations shall characterize the fractional area of block coverage and areal distribution of roughness elements.	SC.1b in Recon Trace Matrix		

	Description/ Clarification	Floor Requirement	Comments	Description/ Clari
RR.1	SC.1 Investigation	15 total sites	Up to 4 (stereo) images are anticipated to be obtained when the trajectory dips sufficiently below 50 km c/a altitude and 1 when c/a altitude is approximately 50 km;	SC.1 Investigation
	SC.1a & SC.1b in Recon Trace Matrix.	2 km x 10 km		SC.1a & SC.1b in Recon Trace Matrix.
	SC.1a in Recon Trace Matrix			SC.1a in Recon Trace Matrix
	SC.1a in Recon Trace Matrix			SC.1a in Recon Trace Matrix
	SC.1a in Recon Trace Matrix			SC.1a in Recon Trace Matrix
	SC.1a in Recon Trace Matrix.	45°-70° goal		SC.1a in Recon Trace Matrix.
	SC.1b in Recon Trace Matrix			SC.1b in Recon Trace Matrix
	SC.1b in Recon Trace Matrix			SC.1b in Recon Trace Matrix
	SC.1b in Recon Trace Matrix			SC.1b in Recon Trace Matrix
	SC.1b in Recon Trace Matrix			SC.1b in Recon Trace Matrix

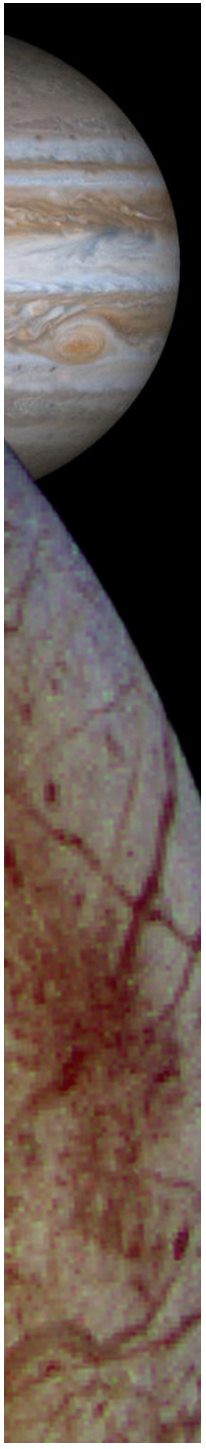


Requirement Mapping to Trace Matrix

Recon Trace Matrix

	Investigation		Measurement	Short name	Model Instrument
SC.1	Determine the distribution of blocks and other roughness elements within a potential landing site at scales that represent a hazard to landing.	SC.1a	Measure the occurrence and lengths of shadows cast by blocks protruding 1 m or more above the surface, and the abundance and nature of surface roughness elements at scales of greater than 1 m, through monochromatic imaging at a spatial resolution on the surface of better than or equal to 0.5 m/pixel.	Blocks	Reconnaissance Camera (RC)

ID			Title	Requirement Text	Description/ Clari
RR.1			Block & Roughness Distribution	The reconnaissance observations shall characterize the distribution of blocks and other roughness elements within 40 potential landing sites at scales that represent a hazard to landing.	SC.1 Investigation
	RR.1.1		Areal Coverage	The visual and thermal imaging areal coverage of potential landing sites shall be 5 km x 10 km.	SC.1a & SC.1b in Recon Trace Matrix.
	RR.1.2		Shadow Characteristics	The reconnaissance observations shall measure the occurrence and lengths of shadows cast by blocks protruding 1 m or more above the surface.	SC.1a in Recon Trace Matrix
		RR.1.2.1	Spatial Resolution of Shadow Imaging	The spatial resolution of monochromatic imaging at the surface shall be better than or equal to 0.5 m/pixel.	SC.1a in Recon Trace Matrix
	RR.1.3		Surface Roughness Elements	The nature and abundance of surface roughness elements shall be measured at scales of greater than 1 meter.	SC.1a in Recon Trace Matrix
		RR.1.3.1	Incidence Angle	The imaging incidence angle shall be between 20° and 80°.	SC.1a in Recon Trace Matrix.



Selected Requirements
Landing Site Surface Properties

RR.2 Slope Distribution

The reconnaissance observations shall characterize the distribution of slopes within 40 potential landing sites over baselines relevant to a lander.

RR.2.1 Slope Angle and Size

Surface slopes shall be measured up to 25° on a 30 to 50 m baseline for all azimuths.

RR.2.1.1 Slope Imaging

The slopes shall be acquired by monochromatic imaging.

RR.2.1.2 Spatial Resolution of Slope Imaging

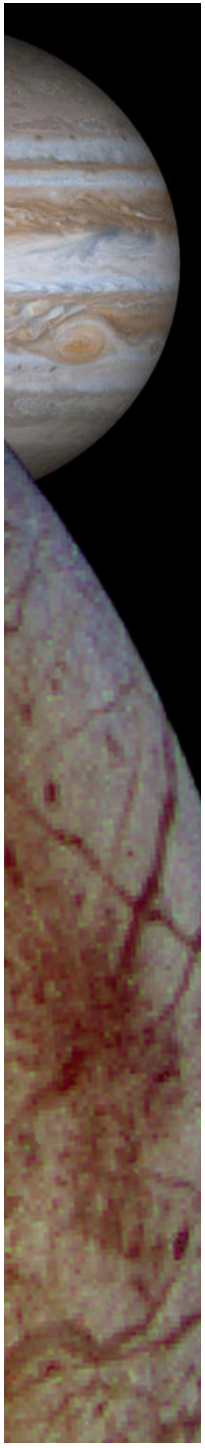
The spatial resolution of slope imaging shall be better than or equal to 7 m/pixel.

RR.2.1.3 Areal Coverage

The imaging areal coverage of the potential landing sites shall be 5 km x 10 km.

RR.2.1.4 Incidence Angle

The incidence angle range shall be 45° - 80°.



Selected Requirements
Landing Site Scientific Value

RR.6 Recent Exposure of Subsurface Ice

The reconnaissance observations shall characterize the potential for recent exposure of subsurface ice or ocean material and resurfacing vs. degradation of the surface by weathering and erosion processes and provide geologic context for 40 potential landing sites.

RR.6.1 Landform Degradation

The reconnaissance observations shall identify small scale landforms, diagnostic of the local geologic history of potential landing sites.

RR.6.1.1 Landform Imaging

The imaging shall be monochromatic stereo.

RR.6.1.2 Spatial Resolution

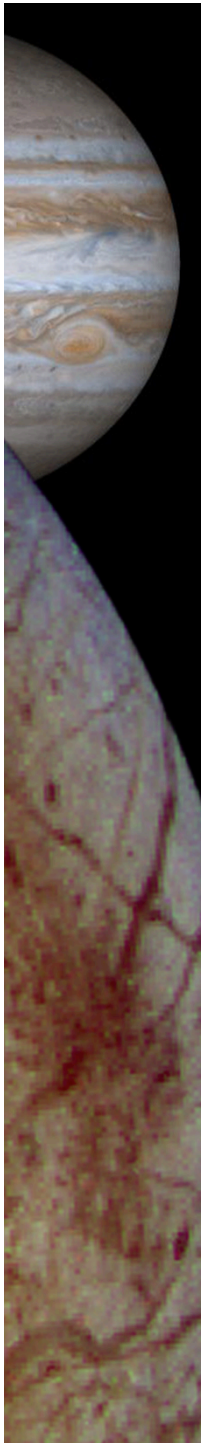
The imaging spatial resolution shall be better than or equal to 0.5 m/ pixel.

RR.6.1.3 Areal Coverage

The areal coverage of the potential landing sites shall be 5 km x 10 km.

RR.6.1.4 Incidence Angle

The imaging data set shall be acquired when the incidence angle is between 20° - 80°.

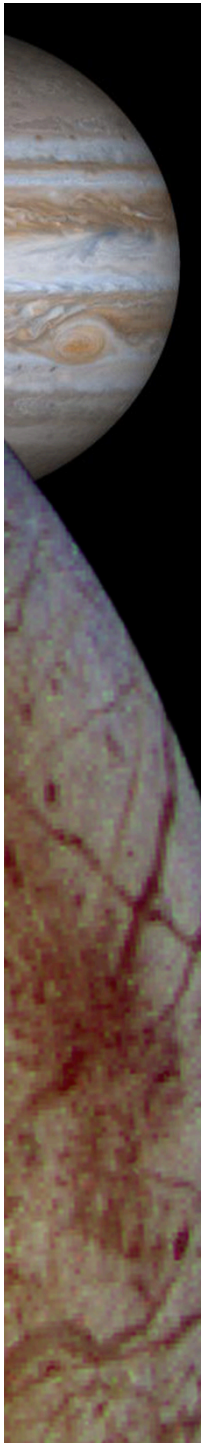


Open Issues

- RR.2.2.3 (IO.4c in STM) - The sounding profile groundtracks shall be co-located with a nadir-pointed altimetric profile to within TBS meters.
- RR.7.3.2 (IO.1b) - Radar penetration depth requirement needs to assume a dielectric property and impurity concentration for Europa's ice sheet to determine two-way attenuation = TBS

From SDT:

J. Connerney: Show clear path to verification for each requirement



Next Steps

- Incorporate SDT comments
- Clarify TBS values, if possible
- Publish preliminary version for MCR in mid June
- Insure requirements can be mapped to the Science Observation Strategy Concept narrative currently under development